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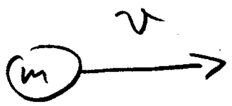
~~4-22~~



$m = 50g \quad v = 30\,m/sec \quad \Delta v = .001\,v = 0.03\,m/sec$

Uncertainty relation $\Delta x \Delta p = \frac{\hbar}{2}$ minimum.

$$\Delta p = m\Delta v = .05\,kg\ .03\frac{m}{sec} = 0.0015\ kg\frac{m}{sec}$$

$$\Delta x = \frac{\hbar}{2\Delta p} = \frac{1.055 \times 10^{-34}\ J\text{-}sec}{2(.0015\ kg\frac{m}{sec})} = 3.52 \times 10^{-32}\ m.\ (!)$$

Try measuring that with a meterstick.

5-19

~~4-23~~

m_p, p, k

$m_p = 938.3\ \frac{MeV}{c^2} \quad K = 1.0\,MeV \quad \Delta p : 5\%$

Since $K \ll m_p c^2$, will use the classical form

$$K = \frac{p^2}{2m_p} \Rightarrow p = \sqrt{2m_pK} = 43.3\ \frac{MeV}{c}$$

$\Delta x \Delta p = \frac{\hbar}{2}$ minimum.

$$\Delta x = \frac{\hbar}{2\Delta p} = \frac{\hbar}{2(.05)(43.3 \times 10^6\ \frac{eV}{c})}$$

$$\Delta x = \frac{6.582 \times 10^{-16}\ eV\text{-}sec}{4.33 \times 10^6\ \frac{eV}{c}} = 4.56 \times 10^{-14}\ m$$

don't forget the c

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Uncertainty principle: $\Delta p \Delta x \geq \frac{\hbar}{2}$

We have $h = 2\pi$ J·sec, whence $\hbar = 1$ J·sec.

Fuzzy has mass $m = 2.0$ kg and the uncertainty in Fuzzy's position is $\Delta x = 1.0$ m.

a) Set $\Delta p \Delta x = \frac{\hbar}{2}$; solve for $\frac{\Delta p}{m}$

$$\Delta p = \frac{\hbar}{2\Delta x} \Rightarrow \Delta v = \frac{\hbar}{2\Delta x\, m}$$

$$\Delta v = \frac{1 \text{ J}\cdot\text{sec}}{2\,(1.0\text{ m})\, 2.0\text{ kg}} = 0.25 \text{ m/sec}$$

b) At constant, but uncertain speed, Fuzzy's position becomes increasing uncertain.

After 5.0 sec, $\Delta x = \Delta x_0 + 5.0\text{ sec} \times \Delta v$

$$= 1\text{ m} + 5\text{ sec}\; 0.25\frac{\text{m}}{\text{sec}}$$

$$= 2.25\text{ m}$$

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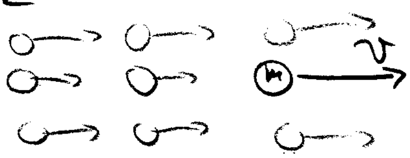
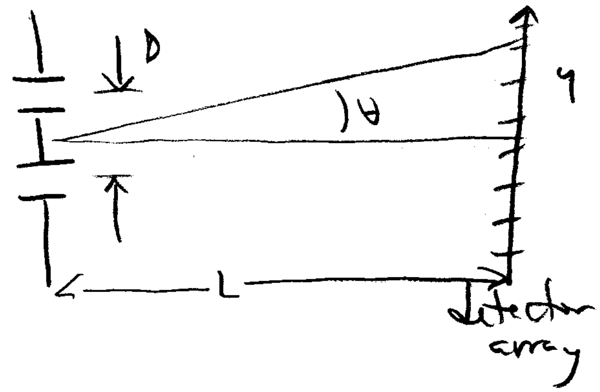
~~4-32~~





$m = 939.6 \frac{MeV}{c^2}$

$v = 0.40$ m/sec

$D = 1.0 \times 10^{-3}$ m

$L = 10$ m

Interference minima occur when $D \sin\theta_m = \frac{m\lambda}{2}$.
Since $L >> D$, we'll say $\sin\theta \approx \tan\theta$.

$$D \frac{y_1}{L} = \frac{\lambda}{2} \Rightarrow y_1 = \frac{\lambda L}{2D}$$

a) $$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{4.136 \times 10^{-15} \text{ eV}\cdot\text{sec}}{936.6 \times 10^{6} \frac{\text{eV}}{c^2} \; 0.40 \text{ m/sec}}$$

$$\lambda = 9.90 \times 10^{-7} \text{ m} = 990 \text{ nm}.$$

b) $$y_1 = \frac{\lambda L}{2D} = \frac{9.90 \times 10^{-7} \text{ m} \; 10 \text{ m}}{(2) \; 1.0 \times 10^{-3} \text{ m}} = 4.95 \times 10^{-3} \text{ m}.$$

c) Notice that $\lambda <<< D$. That's one way, crudely, to determine that we cannot tell which slit a neutron passed through. See the fuller (more careful) discussion on ~~pages 177 and 178.~~

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~~438~~ This one is a little tricky:
The particles are given a momentum along the x-axis. In passing through the hole of diameter d, we have an uncertainty of the particle's y-position of $\Delta y = d$.
Therefore there is an uncertainty in the particle's y-momentum.
Roughly $\Delta P_y \cdot d = h$.

If a particle has a non zero ΔP_y, then some time later, when it has travelled along the x-axis a distance X, the uncertainty in its y-coordinate will be $\Delta y \propto \Delta P_y$. What proportion?

It'll depend on the elapsed time, which in turn is related to X and P_x.
So we'll say $\frac{X}{P_x} = \frac{\Delta y}{\Delta P_y}$.

From above $\Delta P_y = \frac{h}{d}$, and solve for X

$$X = P_x \frac{\Delta y \, d}{h} = \frac{10^{-3}\text{kg} \; 100\frac{\text{m}}{\text{sec}} \; 10^{-2}\text{m} \; 2\times10^{-3}\text{m}}{6.63 \times 10^{-34}\,\text{J sec}}$$

$$X = 3\times10^{27}\text{m}$$

– much greater than the given diameter of the Universe